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INFLUENCE OF PYRITHIOBAC AND INSECTICIDE COMBINATIONS ON COTTON GROWTH AND EARLY SEASON PEST CONTROL

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Plant Pathology and Crop Physiology

by
Richard W. Costello
B.S., Louisiana Tech University, 1992
M.S., University of Arkansas, 1995
December 2000

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ACKNOWLEDGEMENTS

Foremost I thank God for life, guidance, patience, and for allowing me to accomplish all that I have.

To my parents, Dan Richard and Sandra Costello, no words can express the gratefulness for the love and care that you have given me. Thank you for instilling in me the Christian values that have made me who I am. Thank you for believing that I could accomplish this and standing behind me all the way. There is no way to express how blessed I feel to have parents that will encourage me, listen when I need a friend, and share in all my moments of happiness and sorrow. You have truly made my life wonderful.

To Dr. Jim Griffin, thank you for allowing me the opportunity to work in your program and for the guidance and support throughout this project. I especially thank Dr. Roger Leonard for giving me a chance to work with him. Thank you for your guidance on this project and for teaching me from your vast knowledge of agriculture and life. To Dr. Merritt Holman, Dr. Donnie Miller, and Dr. Eric Webster, thank you for guidance and advice and for your friendship. I am grateful and honored to have been part of such a great group.

Thanks to the Department of Plant Pathology staff, Dr. Jonnie Snow, Mrs. Pat Hives, and Mrs. Charletta Warr. I am grateful and forever endebted to Mrs. Pat Hives for keeping me on track, for knocking me back on track when I got off, and for her patience and friendship. There would be no way to keep up with all the dates and paper work without you.

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To my fellow graduate students, I do not believe that graduate school would be bearable if it were not for you. The friendships that I have formed here will be some of the most cherished in my life. You have been with me through some of the hardest times in my life and I am grateful for your support. Special thanks to the Weed Science students Jeff Ellis, Joe Pankey, Alan Peters, Jason Bond, Blaine Viator, David Lonclos, Jeff Masson, and Wei Zhang for their help in my research and school work. To the Entomology students, Jeff Gore, Stacy Hall, Don Cook, Hunter Fife, and Scott Russell for allowing a "weed boy" to be part of their group and for the endless entertainment and card games at Winnsboro during the summers. Thank you all for making the last three years entertaining, fun, and exciting.

To the Northeast Research Station and Macon Ridge Research Station, thank you for allowing me the land, equipment, and labor to conduct this research project. Also, I greatly appreciate Dr. Chuck Kennedy for his assistance and use of the growth chamber used in part of this project. A special thanks to Charles Wilson, Donna Lee, Kiley Sanders, Karen Williams, Karla Torrey, and Ralph Shepherd for assisting me with this project. And to countless summer employees that spent countless hours in the collection of data you are all greatly appreciated.

There are countless others that have been a part of my life that have contributed to who I am now. I thank you my family and friends that have supported and prayed for me during this time.

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ABSTRACT

Field studies were conducted at two locations in Northeast Louisiana, to investigate interactions associated with the herbicide pyrithiobac and insecticide combinations in respect to weed control and insecticide efficacy and cotton response. In addition, controlled environment experiments were conducted to evaluate the effect of temperature regimes and simulated thrips damage on pyrithiobac plus insecticide phytotoxicity to cotton.

Pyrithiobac and insecticide combinations when compared with pyrithiobac alone did not reduce cotton leaf area, height, main stem node number, main stem nodes to first square, days to first square or flower, main stem nodes above white flower, or seedcotton yield. Acephate insecticide alone in one experiment and oxamyl insecticide in two experiments reduced thrips larvae more than when in combination with pyrithiobac. Weed control was equivalent when pyrithiobac was applied alone or in combination with the insecticides acephate, dicrotophos, fipronil, imidacloprid, *lambda*-cyhalothrin, oxamyl, carbofuran, or dimethoate.

Presence of thrips on cotton did not affect cotton tolerance to pyrithiobac. However, differential cotton response to rate of pyrithiobac was observed. Cotton growth not reduced by pyrithiobac applied at four times the labeled rate of 0.07 kg ai/ha compared with nontreated cotton. Leaf area reductions as high as 58% were observed with eight and sixteen times the labeled rate. Significant reductions in cotton height were observed, but varied among years and locations. At Winnsboro, LA, pyrithiobac at 1.22 kg/ha increased total main stem nodes at square initiation by 1.2 nodes. Although significant reductions were observed in leaf area, cotton yield was reduced only in 1998

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by pyrithiobac at 1.22 kg/ha (19%). In an additional study, the presence of thrips or simulated thrips damage did not change cotton tolerance to pyrithiobac regardless of application timing.

In the controlled environment study, cotton response to pyrithiobac was not effected when cotton was stressed under a cool temperature regime (22/10 C day/night for 48 hours prior to application) or terminal removal to simulate thrips damage. Some injury to cotton was observed 7 days after treatment when pyrithiobac was applied with the insecticide malathion or dimethoate but injury was transient and less than 5% 21 days later.

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CHAPTER 1

INTRODUCTION

Prior to 1996, postemergence broadleaf weed control in cotton (*Gossypium hirsutum* L.) was limited primarily to directed applications. Herbicides such as monosodium methane arsenate (monosodium salt of MAA), disodium methane arsenate (disodium salt of MAA), and fluometuron {*N,N*-dimethyl-*N'*-[3-(trifluromethyl)phenyl]urea} are labeled for postemergence over-the-top applications, but crop tolerance in most cases is not acceptable (Frans et al. 1971; Guthrie and York 1989; Houge 1971; Snipes et al. 1992). Pyrithiobac {2-chloro-6-[(4,6-dimethoxy-2-prymidinyl)thio]benzoic acid} represents a new class of herbicide chemistry (benzoates) (Anonymous 1998). Its mode of action is associated with the inhibition of the enzyme acetolactate synthase (E.C.4.1.3.18), the same as that of the sulfonylurea herbicides. Acetolactate synthase is the first enzyme in the biosynthetic pathway in plants and microbes in which the amino acids valine, isoleucine, and leucine are produced (Stidham 1991; Stidham and Singh 1991). Pyrithiobac (trade name Staple[1], E. I. du Pont de Nemours and Co., Wilmington, DE) was introduced as the first postemergence broadleaf weed herbicide for over-the-top application in cotton with acceptable crop safety (Jordan et al. 1993b; Keeling et al. 1993). Snipes et al. (1992) reported no adverse effect of DPX-PE350 (pyrithiobac) on cotton growth, fruiting, or yield, although phytotoxicity was observed with applications to 5 to 7 leaf cotton. Pyrithiobac controls entireleaf morningglory (*Ipomoea hederacea* var. *integruiscula* Gray), pitted morningglory (*Ipomoea lacunosa* L.), common cocklebur (*Xanthium strumarium* L.), and palmer amaranth (*Amaranthus palmeri* Watson) at least 80% when applied postemergence at cotyledon to one true leaf (Everson et al. 1991;

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1 Staple product label. E. I. du Pont de Nemours and Co. Wilmington, DE 19898.

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Keeling et al. 1991; Patterson et al. 1991; Sims et al. 1991; Snipes and Allen 1992; Sunderland and Coble 1994). Sims et al. (1992) and Jordan et al. (1992) reported at least 85% control of velvetleaf (*Abutilon theophrasti* Medicus) when pyrithiobac was applied at 1 to 2 true leaf. Since pyrithiobac application timing in cotton can correspond with that of an insecticide application, the opportunity exists to combine herbicide and insecticide in a single application.

Several species of thrips (Thysanoptera: Thripidae) including tobacco thrips (*Frankiniella fusca* Hinds), flower thrips (*Frankiniella tritici* Fitch), western flower thrips (*Frankiniella occidentalis* Pergande), soybean thrips (*Neohydatothrips variabilis* Beach), and onion thrips (*Thrips tabaci* Lindeman) (Cook et al. 2000) infest cotton fields early in the season around the same time that pyrithiobac would normally be applied. Thrips injure cotton seedlings by feeding on cotyledons, leaves and in the terminal region of the plant (Watts 1937). Thrips scrape holes in plant tissue and feed on cell exudates. Leaves twist, become distorted, and tear as a result of abnormal growth (Telford and Hopkins 1957). Leaves typically exhibit a silvery spotting on the underside as a result of feeding. Thrips feeding can result in an 88% reduction in leaf area and 20% reduction in height when compared with plants treated to control the pest (Carter et al. 1989). In a laboratory study, seedling cotton infested with tobacco thrips was 28% shorter and fresh weight was reduced approximately 50% when compared with nontreated plants (Hightower 1958). Reductions of 80 and 82% in tap root and fine root dry weight, respectively, have been reported as a result of severe thrips feeding (Roberts and Rechel 1996). Reductions in leaf area and root mass directly influence the ability of plants to manufacture photosynthate and extract nutrients from soil. Terminal injury by thrips results in loss of

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apical dominance followed by lateral bud proliferation. Delay in cotton flowering of 2 weeks has resulted from severe thrips injury (Ballard 1951; Carter et al. 1989; Watts 1937). Watts (1937) reported thrips injury delayed first square 10 days and flowering eight days compared with plants not injured. Others reported a 14-day delay in boll set and a significant reduction in lint yield although boll numbers were equivalent (Dunnam and Clark 1937). Fletcher and Gaines (1939) reported that 134 bolls from thrips injured plants were needed to equal the yield of 118 bolls from injury free plants. Carter et al. (1989) noted that even though cotton recovered from early season thrips injury, lint yield was 177 kg/ha less when compared with plants not injured. Early season thrips feeding resulted in a 13% reduction in seedcotton yield (Dunnam and Clark 1937).

For the producer, it would be economically advantageous to co-apply herbicide and insecticide treatments to control weed and insect pests. Combinations of various herbicides and insecticides have resulted in both positive and negative interactions (Hatzios and Penner 1985). These interactions can be synergistic, have no effect, or can be antagonistic. Chang et al. (1971) evaluated the effect of eight insecticides on the metabolism of nine herbicides and found that about half of the combinations exhibited some degree of interaction. Even though not applied in combination, York et al. (1991) found that the insecticides disulfoton {*O,O*-diethyl *S*-[2-(ethylthio)ethyl]phosphorodithioate} and phorate {*O,O* dimethyl S((ethylthio)methyl)-phosphorodithioate} safened cotton against the herbicide clomazone {2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolininone}. Soil incorporated combinations of trifluralin ($\alpha\ \alpha\ \alpha$-trifloro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine) and phorate increased

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seedling growth compared with trifluralin and phorate alone. More lateral roots were produced in cotton plants treated with the combination compared with trifluralin alone (Arle 1968; Hassawy and Hamilton 1971). Another herbicide, bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), increased control of tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois) when applied with the insecticide azinphos-methyl {*O,O*-dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4*H*)-yl)methyl]-phosphorodithioate} (Scott et al. 1996). Tobacco budworm (*Heliothis virescens* F.) survival decreased when cyfluthrin [cyano(4-fluoro-3-phenoxyphenyl)-methyl-3-(2,2-dichloroethynyl)-2,2-dimethylcyclopropanecarboxylate] was applied with bromoxynil (Scott et al. 1996).

Of concern, however, are negative effects that herbicide and insecticide combinations may have on crop safety. Some of the earliest evidence of crop injury with herbicide and insecticide combinations was documented in rice with the herbicide propanil [*N*-(3,4dichlorophenyl)propanamide] and certain organophosphate insecticides (Bowling and Hudgins 1966; Bowling and Flinchum 1968; El-Refai and Mowafy 1973; Smith and Tugwell 1975). Khodayari et al. (1986) reported that the carbamate insecticides carbaryl (1-napthylmethylcarbamate) and methomyl {*S*-methyl *N*-[(methylcarbonyl)oxy)]thioacetimide} also interacted with propanil. Injury was more severe than with the organophosphate insecticide methyl parathion (*O,O*-dimethyl-*O*-4-nitrophenyl phosphorothioate). Applications of propanil to rice treated with granular carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofurany methylcarbamate) resulted in greater injury than propanil alone, but in grain yield, milling quality, or seed viability was not reduced (Smith and Tugwell 1975). These interactions have been attributed to the

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inhibition by these insecticides of aryl acylamidase (ayl-acylamineamidohydrolase EC. 3.5.1.a), a key enzyme in the plant system that hydrolyzes propanil (Frear and Still 1968; Leah et al. 1994; Matsunka 1968). Soybean plant population and grain yield were significantly reduced when the herbicide metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] was applied preemergence at planting following in the seed furrow or soil surface applications of the insecticides phorate or disulfoton (Hayes et al. 1979; Waldrop and Banks 1983). Postemergence applications of bentazon [3-isopropyl-1 *H*-1,2,3-benzothiodiazin-4(3*H*)-one 2,2-dioxide] with certain organophosphate insecticides can result in severe injury to soybean (*Glycine max* (L.) Merr) and navy bean (*Phaseolus vulgaris* L.) (Campbell and Penner 1982). The insecticides disulfoton and phorate reduced the ability of cotton to degrade the herbicide monuron [*N'*-(4-chlorophenyl)-*N,N*-dimethylurea] or diuron [*N'*-(3,4-dichlorophenyl)-*N,N*-dimethylurea] and increased injury from the herbicides (Hacskaylo et al. 1964; Swanson and Swanson 1968). Yield, height reduction, and foliar and root injury have resulted when the herbicide primsulfuron {2-[[[[[4,6-bis(difluoromethoxy)2-prymidinyl]amino]carbonyl]amino]sulfonyl]benzoic acid methyl ester} was applied postemergence to corn treated in the seed furrow at planting with the insecticides disulfoton, fonofos {*O*-ethyl *S*-phenyl ethylphosphonodithioate}, isozophos {*O*-[5-chloro-1-(1-methylethyl)-1*H*-1,2,4-triazol-3-yl] *O,O*-diethyl phosphorothioate}, or terbufos {*S*-[(tert-butylthio)methyl]-*O,O*-diethyl phosphorodithioate} (Biediger et al. 1992). However, corn tolerance to primisulfuron was not affected by the insecticides carbaryl, carbofuran, chlorpyrifos (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl

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phosphorothioate), or diazinon [*O,O*-diethyl *O*-(2-isopropyl-6-methyl-4-pyrimidinyl)phosphorothioate]. Corn tolerance to nicosulfuron {2-[[[[(4,6-dimethoxy-2-(pryimidinyl)amino]carbonyl]amino]sulfonyl]-*N,N*-dimethyl-3-pyridinecarboxamide} is also reduced by in the seed furrow treatments of terbufos resulting in yield loss (Kapusta and Krausz 1992; Morton et al. 1993). Interactions of primisulfuron with terbufos have been attributed to interference in metabolism of the herbicide by the insecticide (Frazier et al. 1993).

Herbicide and insecticide tank mixtures can also affect the herbicide or insecticide efficacy against the target pest. Large crabgrass [*Digitaria sanguinalis* (L.) Scop.] control was reduced when the herbicide sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} was mixed with the insecticide carbaryl (Byrd and York 1988). Barnyardgrass (*Echinochola crus-galli* L. Beauv.) control with the herbicide glyphosate [*N*-(phosphonomethyl)glycine] was significantly reduced when tank mixed with the insecticide imidacloprid {1-[(6-chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine}(Mascarenhas and Griffin 1997).

Based on the research previously discussed, possible interactions associated with mixtures of pyrithiobac and insecticides should be addressed. Research has shown combinations of pyrithiobac plus the insecticides acephate {*O,S*-dimethyl *S*-[*N*-(methylcarbamoyl)methyl]phosphorodithioate}, carbaryl, or dimethoate {*O,O*-dimethyl *S*-[*N*-(methylcarbamoyl)methyl]phosophorodithioate} did not affect cotton maturity or seed cotton yield (Jordan et al. 1993a). The addition of the insecticide malathion to pyrithiobac increased cotton injury when compared with other insecticides co-applied

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with pyrithiobac, however, crop injury was transient (Allen and Snipes 1995). Postemergence applications of pyrithiobac to cotton treated with aldicarb in the seed furrow at planting resulted in greater injury and reduced height when compared with disulfoton, phorate, or acephate in-furrow (Smith et al. 1995).

The possibility of a thrips/pyrithiobac interaction in cotton has been suggested (Baldwin 1996). Corkern et al. (1998) reported that no more than 2% of pyrithiobac is translocated from the treated leaf. Thrips injury to cotton leaves and loss of cell contents may reduce the ability of the plant to metabolize pyrithiobac, therefore, increasing sensitivity.

In addition, an interaction between temperature and thrips injury may play a role in pyrithiobac injury to cotton. Cotton leaf area expansion is affected by temperature, and growth response to temperature has been correlated with leaf area partitioning or expansion (Milthorpe 1959; Potter and Jones 1977). Flint et al. (1983) reported that cotton grown at 32/23 C day/night temperature was taller and produced more dry weight and leaf area than cotton grown at 26/17 C day/night temperature. Thrips feeding can also reduce leaf area, therefore, the combination of thrips feeding and cool temperatures may have a significant effect on phytotoxicity of pyrithiobac to cotton. Allen and Snipes (1995) reported that cool temperature did not increase cotton injury from pyrithiobac. However, injury was increased when pyrithiobac was co-applied with the insecticide malathion. Tolerance of 1 leaf cotton to MSMA was significantly reduced at 13 or 20 C when compared to 31 C (Keeley and Thullen 1971). The pyrithiobac label lists several environmental factors such as cool temperatures, extreme temperature variations, and

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lack of or excessive moisture conditions that may reduce cotton tolerance to pyrithiobac. Wet soil conditions have been reported to reduce cotton tolerance to pyrithiobac (Corkern et al. 1999).

This research addresses the potential interactions associated with selected insecticides representing various chemical families applied with pyrithiobac and also evaluates the effect of thrips and environmental conditions on cotton tolerance to pyrithiobac.

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CHAPTER 2

INFLUENCE OF PYRITHIOBAC AND INSECTICIDE CO-APPLICATIONS ON COTTON PHYTOTOXICITY AND WEED AND INSECT CONTROL

Introduction

Weedy plant and arthropod pests can infest cotton *(Gossypium hirsutum* L) fields at the same time and cause significant yield reductions. Weeds compete with cotton plants for water, nutrients, space, and light. In Louisiana, weeds in cotton cause an estimated annual seed cotton yield reduction of 9% (Byrd 1998a; Byrd 1998b; Byrd 1999). Thrips (Thysanoptera: Thripidae.), an early season insect pest, injure cotton seedlings by feeding on leaves and primordial tissue in the terminal region of the plant (Watts 1937). Thrips can reduce leaf area and plant main stem height, delayed fruiting, and lower yields (Carter et al.1989; Hawkins et al. 1966; Leser 1986; Wilson 1986). Thrips injury to cotton seedlings can result in up to 88% leaf area reduction (Carter et al. 1989), 28% reduction in stem growth and 50% reduction in total plant fresh weight (Hightower 1958). Thrips injury has delayed the initiation of flowering by two weeks and reduced seed cotton yield by up to 13% (Ballard 1951; Carter et al. 1989; Dunnam and Clark 1937; Hawkins et al. 1966; Leser 1989; Watts 1937).

Broadleaf weed control in cotton, until the introduction of pyrithiobac[1] {2-chloro-6-[(4,6-dimethoxy-2-prymidinyl)thio]benzoic acid} in 1996 (Anonymous 1998), was limited to directed applications because of questionable crop safety with herbicides labeled for postemergence over-the-top applications. Pyrithiobac, can be applied postemergence to cotton beginning at one node. This application timing corresponds

[1] Staple product label. E. I. du Pont de Nemours and Co. Wilmington, DE 19898.

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with the period when cotton plants are susceptible to thrips injury. The co-application of herbicide and insecticide for control of both pests is economically advantageous for producers.

However, unexpected phytotoxicity resulting from mixtures or sequential applications of herbicides and insecticides have been observed (Hatzios and Penner 1985). One of the earliest reports of such an interaction was with propanil [(*N*-(3,4-dichlorophenyl)propanamide], a selective herbicide used in rice, *Oryza sativa* L., when mixed with certain organophosphate and carbamate insecticides (Bowling and Hudgins 1966; Bowling and Flinchum 1968; El-Refai and Mowafy 1973; Smith and Tugwell 1975). Increased rice injury was observed when the insecticide carbaryl (1-napthylmethylcarbamate) or methomyl {*S*-methyl *N*-[(methylcarbamoyl)oxy)]thioacetimidate}was applied within seven days before or four days after applications of propanil (Khodayari et al. 1986). The ability of cotton plants to detoxify monuron [*N'*-(4-chlorophenyl)-*N,N*-dimethylurea] or diuron [*N'*-(3,4-dichlorophenyl)-*N,N*-dimethylurea] was reduced when plants were treated with disulfoton {*O,O*-diethyl *S*-[2-(ethylthio)-ethyl]phosphorodithioate} or phorate [*O,O* dimethyl S((ethylthio)methyl)-phosphorodithioate] in the seed furrow at planting (Hacskaylo et al. 1964; Swanson and Swanson 1968). Corn tolerance to the sulfonylurea herbicides, primsulfuron {2-[[[[[4,6-bis(difluoromethoxy)2-rymidinyl]amino]carbonyl]amino]sulfonyl]benzoic acid methyl ester} and nicosulfuron {2-[[[[(4,6-dimethoxy-2-pryimidinyl)amino]carbonyl]amino]sulfonyl]-*N,N*-dimethyl-3-pyridinecarboxamide} is reduced significantly when organophosphate insecticides are applied in the seed furrow at planting (Kapusta and Krausz 1992; Morton et al 1993;

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Reynolds et al. 1991). Postemergence application of primisulfuron to corn treated in the seed furrow with the insecticides terbufos {S-[[(1,1-dimethylethyl)thio]methyl]-*O,O*-diethyl phosphorodithioate}, disulfoton, fonofos (*O*-ethyl *S*-phenyl ethylphosphonodithioate), and isozophos {*O*-[5-chloro-1-(1-methyl ethyl]-1*H*-1,2,4-tiazol-3-yl) *O,O*-diethyl phosphorothioate}resulted in foliage and root injury, reduced heights, and grain losses (Biediger et al. 1992). The insecticide appears to interfere with primisulfuron metabolism (Frazier et al. 1993).

Not only can these interactions result in increased crop injury, but herbicide or insecticide efficacy against the target pest can be affected. Large crabgrass [*Digitaria sanguinalis* (L.) Scop.] control was reduced when the herbicide sethoxydim {2-[1(ethoxyimino)butyl]5-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} was co-applied with the insecticide carbaryl (1-napthyl N-methylcarbamate) compared with sethoxydim alone (Byrd and York 1988). Mascarenhas and Griffin (1997) reported reduced barnyardgrass (*Echinochloa crus-galli* L. Beauv.) control when the herbicide glyphosate [*N*-(phosphonomethyl)glycine] was co-applied with the insecticide imidacloprid {1-[(6-chloro-3-pyridinyl)methyl]-N-nitro-2-imidazolidinimine} compared with glyphosate alone. In contrast to the reductions in control previously mentioned, control of the tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois) with the insecticide azinophos-methyl {O,O-dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)methyl]-phosphorodithioate}was improved by adding the herbicide bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) (Scott et al. 1996).

Co-application of pyrithiobac and early season insecticides will be beneficial to the producer economically and reduce trips across the field. However, due to the

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potential for interactions between a herbicide and insecticide, co-applications of pyrithiobac and insecticides should be investigated. Preliminary studies of pyrithiobac co-applied with selected insecticides produced variable results ranging from increased crop phytotoxicity to no interaction (Allen and Snipes 1995; Jordan et al. 1993a; Seifert et al. 1999). However, these researchers focused their attention on crop phytotoxicity and did not evaluate the effect of the mixtures on insect or weed control. These studies were limited in scope and did not include many of the currently labeled insecticides. The objective of this study was to evaluate the co-application of pyrithiobac with selected insecticides on crop phytotoxicity, insecticide toxicity to thrips, and herbicide efficacy against target weed species.

Materials and Methods

Cotton Phytotoxicity. Studies were conducted in 1998 and 1999 at the Northeast Research Station near St. Joseph, LA, and at the Macon Ridge Location of the Northeast Research Station near Winnsboro, LA. Tests at St. Joseph were conducted on a Commerce silt loam (fine-silty, mixed, nonacid, thermic, Aeric Fluvaquent) with a pH of 5.8 to 6.3 and 0.64 to 0.83% organic matter. The soil at Winnsboro was a Gigger silt loam (fine-silty, mixed, thermic, Typic Fragiudualf) with a pH of 5.8 and 0.92% organic matter. The test areas were treated with 0.84 kg ai/ha trifluralin [2,6-dinitro-*N,N*-dipropyl-4-(trifluromethyl)benzamine] preplant incorporated (PPI) followed by 1.12 kg ai/ha fluometuron preemergence (PRE) {*N,N*-dimethyl-*N*=[3-(trifluromethyl)phenyl]urea.

In 1998, Stoneville 474 (Stoneville Pedigree Seed Co., Memphis, TN 38115) cotton was planted into conventionally tilled beds on May 7 and May 8 at Winnsboro and St. Joseph, respectively. Delta and Pine Land DP 20B (Delta and Pine Land Co., Scott,

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MS 38772) cotton was planted on May 13 at St. Joseph and NuCotn 33B cotton was planted on May 14 at Winnsboro, in 1999. The seed rate in all studies was 15 to 20 per meter of row. The studies at Winnsboro were furrow irrigated beginning at first bloom both years. Aldicarb {2-methyl-2-(meththio)propionaldehyde *O*-(methylcarbamoyl)oxime); Temik, 0.56 kg ai/ha} plus metalaxyl {(*R*)-2-[(2,6-dimethylphenyl)-methoxyacetylamino]-propionic acid methyl ester; Ridomil Gold, 0.94 kg ai/ha} or PCNB [pentachloronitrobenzene plus 5-ethyoxy-3-(trichloromethyl)-1,2,4-thiodazole; Terrachlor Super X, 1.3 kg ai/ha] were applied in the seed furrow at planting. Treatment combinations included pyrithiobac (Staple 85 WP at 0.07 kg ai/ha) alone and co-applied with the following insecticides: acephate (*O,S*-dimethylacetylphoramidothioate; Orthene 90SP at 0.37 kg ai/ha[2]), dicrotophos (dimethyl phosphate of 3-hydroxy *N,N*-dimethyl-*cis*-crotonamide; Bidrin 8EC at 0.37 kg ai/ha[3]), fipronil [5-amino-1-(2,6-dicloro-4-(trifluromethyl) phenyl)-1-((1,*R,S*)-(trifluromethyl)sulfinyl)-1-*H*-pyrazole-3-carbonitrile; Regent 2.5EC at 0.056 kg ai/ha[4]], imidacloprid {1-[(6-cloro-3-pryimidinyl)methyl]-*N*-nitro-2imidazolidinimine; Provado 1.6F at 0.052 kg ai/ha[5]}, *lambda*-cyhalothrin [1α(*S**),3α(*Z*)]-(±)-cyano-(3-phenoxyphenyl)methyl-3-(2-chloro-3,3,3-trifluro-1-prophenyl)-2,2-dimethylcyclopropanecarboxylate; Karate 1E at 0.037 kg ai/ha[6]], oxamyl {methyl *N*=,*N*=-dimethyl-*N*-[(methylcarbamoyl)oxy]-1-thioxamimidate]; Vydate 3.7L at 0.28 kg

[2] Orthene product label. Valent USA Co. Walnut Creek, CA 94596-8025.
[3] Bidrin product label. E. I. du Pont de Nemours and Co. Wilmington, DE 19898.
[4] Regent product label. Rhone-Pouenc AG Co. Research Triangle Park, NC 27709.
[5] Provado product label. Bayer Co. Crop Protection Products. Kansas City, MO 64120-0013.
[6] Karate product label. Zeneca Ag Products. Wilmington, DE 19850-5458.

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ai/ha[7]}, carbofuran (2,3-dihydro-2,2dimethyl-7-benzofuranyl methylcarbamate; Furadan 4F at 0.28 kg ai/ha[8]), and dimethoate {*O,O*-dimethyl S-[N-methylcarbamoyl)methyl] (phosphororithioate); Dimate 4EC at 0.28 kg ai/ha[9]}. A nonionic surfactant (Ag-98®[10] at 0.25% v/v) was added to each treatment. Treatments were applied when cotton plants reached 2 to 3 nodes. Applications were made using a tractor-mounted compressed air sprayer at St. Joseph and a CO_2 pressurized backpack sprayer at Winnsboro with both calibrated to deliver 140 L/ha.

Cotton phytotoxicity was determined with a visual injury rating based on a scale of 0 (no injury) to 100% (plant death) at 7 and 14 days after treatment (DAT) or until visual symptoms were not evident. Visual injury was based on plant chlorosis. Leaf area and total main stem nodes per plant were taken at 7, 14, and 28 DAT from a 0.5 m section of row. Leaf area was measured using a LI-Cor LI-3000 Area Meter[11]. The number of main stem nodes at square initiation was determined at the same time leaf area was measured 28 DAT. Plant height was determined by randomly measuring 10 plants in each plot 7, 14, and 28 DAT. Days from planting to first square and first flower were recorded for plants from a 1-m section of row. The nontreated control was monitored until 50% of the plants in the sample area produced one square or one flower and then sampling plants in each treated plot. Plots averaging at least 50% of the plants with a square or flower in the 1-m row section were recorded as being at first square or flower.

[7] Vydate product label. E. I. du Pont de Nemours and Co. Wilmington, DE 19898.
[8] Furadan product label. FMC Co. AG Products. Philadelphia, PA 19103.
[9] Dimate product label. Terra Industries Inc., Sioux City IA, 51102-6000.
[10] AG-98 is a blend of alkylaryl polyethylene glycols and alchol. Rohm and Haas Co. Philadlephia, PA 19106-2399.
[11] LICOR, Inc. Lincoln, NE 68504.

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Nodes above white flower (NAWF) measurements were recorded weekly after flower initiation by randomly sampling 10 plants from each plot. These experiments were grown using standard production practices. Plots were mechanically harvested using a spindle type picker.

The experimental design was a randomized complete block with four replications at St. Joseph and three replications at Winnsboro. Plot size consisted of 4 rows (1-m spacing) by 14-m at St. Joseph and two rows (1-m spacing) by 14-m and two rows (1-m spacing) by 10 m at Winnsboro in 1998 and 1999, respectively. Data were subjected to analysis of variance and means were separated using Fisher's Protected least significant difference (LSD) at the 0.05 level of probability.

Insecticide Efficacy. Studies were conducted in 1997 at the Northeast Research Station, near St. Joseph, LA, and at the Macon Ridge Location of the Northeast Research Station, near Winnsboro, LA, in 1997 and 1998 to evaluate insecticide efficacy against thrips for pyrithiobac plus insecticide co-applications. The insecticides were identical to those used in the cotton phytotoxicity study. A nonionic surfactant (Ag-98® at 0.25% v/v) was added to each treatment. Cotton was treated when thrips densities were ≥ 2 insects per plant. Applications were made using a tractor mounted compressed air sprayer at St. Joseph and a CO_2 pressurized backpack sprayer at Winnsboro with both calibrated to deliver 140 L/ha. Ten plants were randomly sampled from each plot at 2 and 5 DAT and placed in 0.94 L glass jars until they were processed. Whole plant washing techniques described by Burris et al. (1990) were used to separate thrips from freshly harvested cotton plants. Thrips numbers were determined using the aid of a binocular

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dissecting scope. The experimental design for each study was a randomized complete block with four replications. Plot size consisted of 3 rows (1-m spacing) by 6 m. Data were subjected to analysis of variance and treatment comparisons were made using single degree of freedom contrast analysis (P=0.1).

An experiment was conducted in 1998 at the Macon Ridge Research Station near Winnsboro, to evaluate the efficacy of selected adjuvants on thrips. Treatments included pyrithiobac, Staple 85WP at 0.07 kg /ha; acephate, Orthene 90SP at 0.37 kg/ha; nonionic surfactant, Activate Plus®[12] at 0.25% v/v and AG-98® at 0.25% v/v; organosilicone, Silkin®[13] at 0.125% v/v; crop oil, Prime Oil®[14] at 0.5% v/v; methylated seed oil, Meth Oil®[15] at 0.5% v/v; organosilicone plus methylated seed oil, Rivet®[16] at 0.125% v/v and Dyne-Amic®[17] at 0.5% v/v; methylated seed oil plus nonionic surfactant, Sun-It II®[18] at 1.0% v/v; nonionic surfactant plus ammonium sulfate, AMS Plus®[19] at 0.5% v/v; and nonionic surfactant plus 28% nitrogen solution, Chaser®[20] at 0.25% v/v. Cotton was treated when thrips were ≥ 2 insects per plant. Treatments were applied with a CO_2

[12] Activate Plus® is a blend of alkyl arylpolyoxyethylene glycols, free fatty acids and IPA. Terra Industries Inc., Sioux City IA, 51102-6000.
[13] Silkin ® is a blend of polymethylsiloxane copolymer and polyethoxy ethers. Terra Industries Inc., Sioux City IA, 51102-6000.
[14] Prime oil® is a crop oil concentrate consisting of paraffinic oils and emulsifiers. Terra Industries Inc., Sioux City IA, 51102-6000.
[15] Meth oil® is a crop oil concentrate containing methylated seed oils. Terra Industries Inc., Sioux City IA, 51102-6000.
[16] Rivet® is a blend of methylated seed oil plus organosilicone and nonionic wetting agents. Terra Industries Inc., Sioux City IA, 51102-6000.
[17] Dyne-Amic® is a blend of phosphorylated alkylpolyethoxylates, polyethoxylated dimethyl siloxanes, alkylarylethoxylates and methytlated seed oil. Helena Chemical Co., Memphis, TN 38119.
[18] Sun-It II® is a crop oil concentrate containing methylated seed oil and emulsifying surfactants. AGSCO, Inc., Grand Forks, ND 58206-0458.
[19] AMS Plus® is a blend of ammonium sulfate and glycerol acid phosocitrate complex. Terra Industries Inc., Sioux City IA, 51102-6000.
[20] Chaser is a blend of nitrogen solution and nonionic surfactants. Terra Industries Inc., Sioux City IA, 51102-6000.

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pressurized backpack sprayer calibrated to deliver 140 L/ha. Plot size was 2 rows (1-m spacing) by 6 m. Plants were collected and processed as previously described. Data were subjected to analysis of variance and means separated by Fisher's Protected LSD at the 0.05 level of probability.

Weed Control. Experiments were conducted in 1997 at the Northeast Research Station, near St. Joseph and in 1999 at St. Joseph and the Macon Ridge Location of the Northeast Research Station near Winnsboro, to evaluate weed control with pyrithiobac co-applied with various insecticides. Treatments were the same as those described for the cotton phytotoxicity study. A nonionic surfactant (Ag-98® at 0.25% v/v) was added to each treatment. Experiment one, at St. Joseph in 1997, was conducted in a fallow area with a natural infestation of pitted morningglory (*Ipomoea lacunosa* L.), entireleaf and ivyleaf morningglory mix (*Ipomoea hederacea*), hemp sesbania [*Sesbania exaltata* (Raf.)] and prickly sida (*Sida spinosa* L.). In the second experiment, at St. Joseph in 1997, the same weed species were planted in rows using a push planter. In 1999, the same weeds with the addition of velvetleaf (*Abutilon theophrasti* Medicus) were planted at both locations in rows using a push planter. The weeds chosen in these experiments represent some of the most troublesome and hard to control in the south. Pyrithiobac plus insecticide combinations were applied perpendicular to the planted weed rows. Weed size at the time of application ranged from 3 to 5 leaf. Applications were made using a CO_2 pressurized backpack sprayer calibrated to deliver 140 L/ha.

Weed control ratings were based on a visual scale of 0 (no injury) to 100% (plant death) and were taken at 7, 14, and 28 DAT. In addition, dry weight of surviving weed

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species were determined by harvesting weeds from 0.5 m section of each row from each plot at 14 and 28 DAT and sufficiently drying for five days in a greenhouse at 55 C and recording the sample weights. The experimental design was a randomized complete block with four replications and plot size was 2.5 by 4 m. Data were subjected to analysis of variance and means were separated using Fisher=s protected LSD at the 0.05 level of probability. Contrast analysis (*P*=0.05) was also performed to determine if there were any differences among the average of all pyrithiobac and insecticide combinations and pyrithiobac applied alone.

Results and Discussion

Cotton Phytotoxicity. Analysis of variance revealed no significant treatment by year or location interactions, therefore, all data were averaged across years and locations. Leaf area per plant in the nontreated (91 cm^2) at 7 DAT was greater than all treatments except pyrithiobac plus dicrotophos (81 cm^2) and pyrithiobac plus fipronil (79 cm^2) (Table 2.1). Leaf area at 14 and 28 DAT was equivalent for the various treatments. No differences were observed for plant height at any rating date and numerical differences among treatments were no greater than four centimeters. Pyrithiobac or pyrithiobac plus insecticide co-applications did not affect total nodes per plant at any rating date compared with the nontreated.

No differences in plant injury among pyrithiobac plus insecticide co-applications were observed at 7 or 14 DAT (Table 2.1). However, differences between years did exist. Averaged across locations and treatments, injury was greater in 1998 (20%) than 1999 (9%) at 7 DAT (data not shown). Much drier conditions prevailed in 1998 and cotton

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Table 2.1. Leaf area, height, total nodes, and injury for cotton seedlings following pyrithiobac applied alone and in combination with selected insecticides[a].

Treatment[b]	Application rate	Leaf area			Height			Main stem node			Injury	
		7[c]	14	28	7	14	28	7	14	28	7	14
	kg ai/ha	——cm^2——			——cm——			——no.——			——%——	
Pyrithiobac	0.07	71	220	1055	14	28	41	4.3	7.0	12.1	16	4
Acephate	0.37	66	233	1104	14	29	39	4.2	7.0	12.4	16	5
Dicrotophos	0.37	81	242	1027	14	28	39	4.4	7.5	12.4	15	4
Fipronil	0.06	79	213	987	14	30	42	4.3	7.1	12.3	17	4
Imidacloprid	0.05	76	214	939	14	27	41	4.3	7.0	12.0	16	4
Lambda-cyhalothrin	0.03	74	203	1098	14	29	41	4.4	7.0	12.0	16	4
Oxamyl	0.28	76	205	967	14	28	41	4.1	7.1	12.0	17	5
Carbofuran	0.28	65	219	1063	14	28	43	4.1	7.2	12.3	19	6
Dimethoate	0.28	70	233	1083	14	28	40	4.3	7.2	12.0	17	5
Nontreated	--	91	220	1174	14	28	43	4.3	7.0	12.0	0	0
LSD (0.05)		12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a]Data represent an average across years and locations. Leaf area represents total leaf area from 0.5m of row divided by the number of plants. Cotton height was based on a measurement from soil to the terminal of the plant. Total nodes were determined by counting to the newest unrolled leaf in the terminal and using the cotyledonary node as 0.

[b]Pyrithiobac co-applied with all insecticides at 0.07 kg ai/ha.

[c]Days after treatment.

seedlings were stressed thereby predisposing plants to injury. This injury appeared to be transient and was less than 6% at 14 DAT and no injury was observed 28 DAT. Data are consistent with those of others who reported at least 25% visual plant injury with labeled rates of pyrithiobac (Crawford et al. 1989; Jordan et al. 1993a; Jordan et al. 1993b; Keeling et al. 1993; Snipes et al. 1992)

Pyrithiobac and co-applications of pyrithiobac plus insecticides had no effect on nodes to first square or days to first square or first flower (Table 2.2). Averaged across treatments, the first square was observed on node 6 or 7 (0 = 6.5). The first square generally appears on nodes 5 or 6 depending on temperature and moisture conditions after planting. Days to first square and first flower were 36 and 60, respectively, averaged across treatments. Oosterhuis (1992) reported that plants require approximately 27 to 38 days from emergence to reach first square and 60 to70 days from emergence to reach first flower depending on environmental conditions. Cotton plants in these experiments were growing normally and differences in these parameters between years and locations were a result of variations in irrigation, rainfall and heat unit accumulations. NAWF were not effected by pyrithiobac or pyrithiobac plus insecticide co-applications compared with the nontreated.

Seed cotton yield was 2620 to 3000 kg/ha (Table 2.2). No differences were observed among the treatments. Differences in seed cotton yield between locations and years could be attributed to variations in irrigation and rainfall patterns.

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Table 2.2. Nodes to first square, days to square initiation and first flower, node above white flower (NAWF), and seedcotton yield following pyrithiobac applied alone and in combination with selected insecticides[a].

Treatment[b]	Application rate	Nodes to first square	Days to first square[c]	Days to first flower[c]	NAWF2[d]	NAWF3	NAWF4	Seed cotton yield
	kg ai/ha	——no.——			——no.——			kg/ha
Pyrithiobac	0.07	6.3	37	60	7.0	5.6	4.0	2867
Acephate	0.37	6.5	37	60	6.8	5.8	4.0	2982
Dicrotophos	0.37	6.6	36	58	6.8	5.6	3.9	3000
Fipronil	0.06	6.4	36	59	6.8	5.6	4.3	2997
Imidacloprid	0.05	6.3	36	60	6.7	5.7	4.2	2794
Lambda-cyhalothrin	0.03	6.4	37	59	6.5	5.3	4.0	2620
Oxamyl	0.28	6.7	37	60	6.9	5.4	4.2	2823
Carbofuran	0.28	6.6	37	60	6.5	5.6	4.1	2849
Dimethoate	0.28	6.7	37	61	6.9	6.0	4.5	2882
Nontreated	--	6.3	36	59	6.8	5.7	4.1	2748
LSD (0.05)		NS	NS	NS	NS	NS	NS	NS

[a] Data represent an average across years and locations. Nodes to first square were counted at the time leaf area was determined 28 DAT.

[b] Pyrithiobac co-applied with all insecticides at 0.07 kg ai/ha.

[c] Represents number of days from planting when 50% of the plants in a one meter section of row in each plot reached first square or first flower.

[d] Represents week two, three and four of cotton flowering.

Thrips Studies. Differences were observed among experiments, therefore, data for each experiment will be discussed separately. Thrips control averaged across all pyrithiobac plus insecticide combinations was equivalent to that for all insecticides alone. Also, thrips numbers in pyrithiobac treatments and the nontreated were not different, therefore, all comparisons were made to the nontreated.

At St. Joseph in 1997, imidacloprid reduced thrips larvae compared with the nontreated (P=0.0304), however, when imidacloprid was co-applied with pyrithiobac thrips larvae numbers were not reduced (P=0.1660) compared with the nontreated (Table 2.3). Total number of thrips were reduced by imidacloprid alone (P =0.0493), but were not reduced when imidacloprid was co-applied with pyrithiobac (P =0.2751) compared with the nontreated control. Oxamyl alone controlled thrips larvae (P=0.0506) significantly greater than pyrithiobac plus oxamyl (P=0.4579) compared with the nontreated. Total thrips were significantly reduced by oxamyl alone (P=0.0680), but not by the combination of pyrithiobac plus oxamyl (P=0.4867) compared with the nontreated. However, pyrithiobac plus dimethoate controlled adult thrips (P=0.0566) better than dimethoate alone (P=0.2043) compared with the nontreated.

At Winnsboro in 1997, dimethoate reduced adult and total thrips when applied alone, but did not reduce thrips numbers when applied with pyrithiobac (Table 2.4). Dimethoate alone (P=0.0947) reduced thrips larvae compared with the nontreated, however, in combination with pyrithiobac, thrips larvae were not reduced compared with the nontreated (P=0.6068). All other treatments provided equivalent control either alone or in combination with pyrithiobac compared with the nontreated. In 1998 at Winnsboro, treatments of dicrotophos alone resulted in lower thrips numbers than dicrotophos plus

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Table 2.3. **Efficacy of pyrithiobac and selected pyrithiobac-insecticide co-applications on control of thrips 5 days after treatment and single degree of freedom contrast analysis at St. Joseph during 1997.**

Treatment	Application rate	Thrips/10 plants		
		Adults	Larvae	Total
	kg ai/ha	no.		
Acephate	0.37	5	16	22
Acephate + pyrithiobac	0.37 + 0.07	7	32	39
Dicrotophos	0.37	8	16	25
Dicrotophos + pyrithiobac	0.37 + 0.07	10	26	36
Fipronil	0.05	3	19	22
Fipronil + pyrithiobac	0.05 + 0.07	7	18	25
Imidacloprid	0.05	15	28	44
Imidacloprid + pyrithiobac	0.05 + 0.07	20	39	59
Lambda-cyhalothrin	0.03	6	8	14
Lambda-cyhalothrin + pyrithiobac	0.03 + 0.07	7	13	20
Oxamyl	0.28	15	32	47
Oxamyl + pyrithiobac	0.28 + 0.07	18	48	66
Carbofuran	0.28	23	40	63
Carbofuran + pyrithiobac	0.28 + 0.07	28	42	70
Dimeothate	0.28	12	33	45
Dimethoate + pyrithiobac	0.28 + 0.07	8	23	31
Pyrithiobac	0.07	14	42	56
Nontreated	--	20	58	78
Contrasts		*P*	*P*	*P*
Imidacloprid vs nontreated		--[a]	0.0304	0.0493
Imidacloprid + pyrithiobac vs nontreated		--	0.1660	0.2751
Oxamyl vs nontreated		--	0.0506	0.0680
Oxamyl + pyrithiobac vs nontreated		--	0.4579	0.4867
Dimethoate vs nontreated		0.2043	0.0620	0.0527
Dimethoate + pyrithiobac vs Dimethoate		0.0566	0.0110	0.0071

[a]Represents contrasts that were not significant.

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Table 2.4. Efficacy of pyrithiobac and selected pyrithiobac-insecticide co-applications on control of thrips 5 days after treatment and single degree of freedom contrast analysis at Winnsboro during 1997.

Treatment	Application rate	Thrips/10 plants		
		Adults	Larvae	Total
	kg ai/ha	no.		
Acephate	0.37	4	5	9
Acephate + pyrithiobac	0.37 + 0.07	1	1	2
Dicrotophos	0.37	2	5	7
Dicrotophos + pyrithiobac	0.37 + 0.07	2	3	5
Fipronil	0.05	1	3	4
Fipronil + pyrithiobac	0.05 + 0.07	2	3	5
Imidacloprid	0.05	1	6	7
Imidacloprid + pyrithiobac	0.05 + 0.07	1	8	9
Lambda-cyhalothrin	0.03	1	5	6
Lambda-cyhalothrin + pyrithiobac	0.03 + 0.07	1	2	3
Oxamyl	0.28	2	3	5
Oxamyl + pyrithiobac	0.28 + 0.07	1	3	4
Carbofuran	0.28	1	7	8
Carbofuran + pyrithiobac	0.28 + 0.07	4	3	7
Dimeothate	0.28	1	2	3
Dimethoate + pyrithiobac	0.28 + 0.07	2	6	8
Pyrithiobac	0.07	2	6	8
Nontreated	--	4	8	12
Contrasts		*P*	*P*	*P*
Dimethoate vs nontreated		0.0426	0.0947	0.0504
Dimethoate + pyrithiobac vs nontreated		0.1121	0.6068	0.3852

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pyrithiobac (P=0.0945). Dicrotophos alone controlled thrips larvae (P=0.1056) significantly greater than when in combination with pyrithiobac. In 1998 at Winnsboro, treatments of dicrotophos alone resulted in lower thrips numbers than dicrotophos plus pyrithiobac (P=0.0945). Dicrotophos alone controlled thrips larvae (P=0.1056) more than when in combination with pyrithiobac (P =0.1878) compared with the nontreated (Table 2.5). Pyrithiobac plus oxamyl did not reduce thrips larvae or total thrips compared with the nontreated, however, oxamyl alone resulted in reductions in thrips larvae and total thrips. Adult thrips were controlled better with carbofuran alone compared with the nontreated than when in combination with pyrithiobac. When co-applied with pyrithiobac, dimethoate did not reduce thrips larvae, but dimethoate applied alone reduced thrips larvae compared with the nontreated (Table 2.5).

There were no differences among adjuvant treatments for adult thrips 2 DAT (Table 2.6). Thrips larvae in cotton treated with acephate alone, Rivet®, Silkin®, Activate Plus®, or Meth Oil® were equivalent to the nontreated control 2 DAT. Thrips larvae were from 62 to 97 per 10 plants on cotton treated with pyrithiobac, Dyne-amic®, Prime Oil®, Sun-It II®, Chaser®, AMS Plus®, and AG-98® with all being higher than the nontreated. All treatments with the exception of pyrithiobac and AG-98® resulted in total thrips control equivalent to the nontreated. With the exception of Activate Plus® and Meth Oil®, total thrips were higher on cotton treated with adjuvants compared with acephate treated cotton.

At 5 DAT, pyrithiobac averaged 17 adult thrips per 10 plants which was less than all other treatments except acephate which averaged 28 adult thrips per plant (Table 2.6).

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Table 2.5. **Efficacy of pyrithiobac and selected pyrithiobac-insecticide co-applications on control of thrips 5 days after treatment and single degree of freedom contrast analysis at Winnsboro during 1998.**

Treatment	Application rate	Thrips/10 plants Adults	Larvae	Total
	kg ai/ha	no.		
Acephate	0.37	2	25	27
Acephate + pyrithiobac	0.37 + 0.07	3	34	37
Dicrotophos	0.37	10	45	55
Dicrotophos + pyrithiobac	0.37 + 0.07	5	54	59
Fipronil	0.05	4	12	16
Fipronil + pyrithiobac	0.05 + 0.07	3	11	14
Imidacloprid	0.05	8	80	88
Imidacloprid + pyrithiobac	0.05 + 0.07	5	34	38
Lambda-cyhalothrin	0.03	5	18	48
Lambda-cyhalothrin + pyrithiobac	0.03 + 0.07	3	25	28
Oxamyl	0.28	4	32	36
Oxamyl + pyrithiobac	0.28 + 0.07	4	55	59
Carbofuran	0.28	7	77	84
Carbofuran + pyrithiobac	0.28 + 0.07	6	142	148
Dimeothate	0.28	5	33	38
Dimethoate + pyrithiobac	0.28 + 0.07	5	103	108
Pyrithiobac	0.07	8	143	151
Nontreated	--	8	93	101
Contrasts		*P*	*P*	*P*
Dicrotophos vs nontreated		--[a]	0.1056	--
Dicrotophos + pyrithiobac vs nontreated		--	0.1878	--
Dicrotophos + pyrithiobac vs Dicrotophos		0.0945	--	--
Oxamyl vs control nontreated		--	0.0556	0.0512
Oxamyl + pyrithiobac vs contro nontreated		--	0.1935	0.1767
Carbofuan + pyrithiobac vs Carbofuran		--	0.0416	--
Dimethoate vs nontreated		--	0.0425	0.0426
Dimethoate + pyrithiobac vs nontreated		--	0.7238	0.8118

[a]Represents contrasts that were not significant.

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Table 2.6. Toxicity of selected adjuvants pyrithiobac, and acephate to thrips adults, larvae and total thrips, 2 and 5 DAT at Winnsboro during 1997.

Treatment	Application rate	2 DAT Adults	2 DAT Larvae	2 DAT Total	5 DAT Adults	5 DAT Larvae	5 DAT Total
	% v/v	Thrips/10 plants					
Dyne-amic	0.5	17	72	88	35	71	106
Rivet	0.125	11	58	71	34	51	88
Silkin	0.125	13	58	70	41	59	100
ActivatePlus	0.25	12	38	50	35	66	101
Meth Oil	0.5	17	41	60	38	65	102
Prime Oil	0.5	14	63	76	31	53	84
Sun-it II	1.0	16	68	85	34	81	158
Chaser	0.25	15	92	97	34	57	90
AMS Plus	0.5	16	63	88	33	75	108
AG-98	20.25	18	97	115	30	60	90
Acephate	0.33[a]	7	25	32	28	9	41
Pyrithiobac	0.07[a]	15	88	103	17	42	60
Nontreated	--	10	49	61	33	62	95
LSD(0.05)	--	NS	28	34	13	28	37

[a]Acephate and pyrithiobac rates in kg ai/ha.

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Thrips larvae were reduced in cotton treated with acephate compared with the nontreated. All other treatments except Dyne-amic® and Sun-It II® resulted in thrips larvae equivalent to the nontreated control. Thrips larvae numbers were greater in cotton treated with Dyne-amic® and Sun-It II® compared with the nontreated. Total thrips in cotton treated with acephate, although equivalent with pyrithiobac, was lower than all other treatments.

Adjuvants effect insecticide efficacy in several ways. Oils, such as vegetable or mineral, may improve the deposition of the insecticide to the plant and reduce evaporative losses, therefore, exposing the insects to more insecticide (McDaniel 1980; Southwick et al. 1986). It has been reported that soybean and cotton seed oil formulations of permethrin slowed leaf penetration when compared to aqueous dilutions (Southwick et al. 1983). Slower penetration causes the insect to be in contact with the poison a longer period of time. Oils may also increase efficacy by dissolving epicuticular waxes and disrupting internal protein organization of the cuticle facilitating passage of certain insecticides (Matsumura 1975). The oils may be toxic to the pest. Mineral oils that interfere with the respiration of insects may be synergystic to certain insecticides that act on the nervous system (Ishaaya et al. 1986).

Weed Control. No treatment by year or treatment by location interactions were observed for weed control, therefore, data were averaged across years and locations. None of the insecticides affected weed control with pyrithiobac. Control was 92 to 94%, 97 to 99%, 69 to 75%, 81 to 93%, and 92 to 98%, 28 DAT, for pitted morningglory, hemp sesbania, prickly sida, velvetleaf, and entireleaf/ivyleaf morningglory, respectively (Table 2.7).

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Table 2.7. Control of pitted morningglory, hemp sesbania, prickly sida, velvetleaf, and entire/ivyleaf morningglory with pyrithiobac and pyrithiobac plus insecticide combinations 14 and 28 days after treatment[a].

Treatment[c]	Application rate	IPOLA[b]		SEBEX		SIDSP		ABUTH[d]		IPOHE	
		14	28	14	28	14	28	14	28	14	28
	kg ai/ha	%									
Pyrithiobac	0.07	82	92	98	97	77	75	85	87	79	98
Acephate	0.37	80	93	98	97	77	73	85	87	79	93
Dicrotophos	0.37	81	92	97	97	77	69	89	88	81	92
Fipronil	0.06	80	92	98	97	74	70	91	94	78	94
Imidacloprid	0.05	83	93	97	97	78	71	84	88	79	93
Lambda-cyhalothrin	0.03	80	93	98	98	78	73	91	93	79	95
Oxamyl	0.28	79	93	98	98	76	69	88	81	79	93
Carbofuran	0.28	80	93	98	99	77	70	85	87	76	92
Dimethoate	0.28	80	94	98	98	76	73	91	82	75	94
LSD (0.05)	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a]Data represent an average across years (1997 and 1999) and locations (St. Joseph and Winnsboro, LA).

[b]Abbreviations: IPOLA, pitted morningglory; SEBEX, hemp sesbania; SIDSP, prickly sida; ABUTH, velvetleaf; IPOHE, mix of entireleaf and ivyleaf morningglory.

[c]Pyrithiobac co-applied with all insecticides at 0.07 kg ai/ha.

[d]Velvetleaf evaluated only in 1999

Dry weights revealed similar results as the control ratings. A location effect was observed for dry weight. Dry weight of weeds was greater at St. Joseph compared with Winnsboro, however, this could be attributed to a higher rainfall at St. Joseph (12.5 vs 2.2 cm) during the experiment. Dry weight data represent an average across locations. All treatments reduced weed dry weight compared with the nontreated (Table 2.8). Hemp sesbania dry weight was lower with pyrithiobac plus dicrotophos and pyrithiobac plus oxamyl compared with pyrithiobac alone 14 DAT (Table 2.8). However, no differences in dry weight was observed between pyrithiobac alone and pyrithiobac plus insecticide combinations 28 DAT. Contrast analysis to compare all pyrithiobac and insecticide combinations to pyrithiobac alone revealed no differences. Jordan et al. (1993a) reported that acephate, carbaryl, or dimethoate did not effect entireleaf morningglory control with pyrithiobac. Others have reported entireleaf morningglory control with pyrithiobac alone to be greater than 80% when applied at a rate of 0.08 kg/ha to 6 to 10 leaf weeds (Vidrine et al. 1990). Pitted morningglory control with pyrithiobac from 82 to 95%, depending on application timing and environmental conditions, has been reported (Crawford et al. 1989; Sims et al. 1992; Sunderland and Coble 1994; Vidrine et al. 1990). Sims et al. (1992) reported at least 85% control of velvetleaf with pyrithiobac. Hemp sesbania control was reported to be more than 95% by Vidrine et al. (1990) and more than 88% by Crawford et al. (1989).

Crop phytotoxicity experiments suggest that pyrithiobac plus insecticides can be applied to 2 to 3 node cotton without adverse effects on cotton growth. Currently, malathion is the only insecticide restricted on the pyrithiobac label (Anonymous 2000). Increased cotton injury when pyrithiobac is co-applied with malathion has been

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Table 2.8. Dry weight of pitted morningglory, hemp sesbania, prickly sida, velvetleaf, and entire/ivyleaf morningglory with pyrithiobac-insecticide combinations 14 and 28 days after treatment[a].

Treatment[c]	Application rate	IPOLA[b]		SEBEX		SIDSP		ABUTH		IPOHE	
		14	28	14	28	14	28	14	28	14	28
	kg ai/ha	grams									
Pyrithiobac	0.07	16.3	5.8	7.0	1.0	5.0	13.0	5.2	1.3	10.3	5.1
Acephate	0.37	17.2	4.0	5.0	1.0	4.9	11.2	3.3	1.0	19.2	4.0
Dicrotophos	0.37	17.5	3.7	2.4	0.6	6.5	15.3	5.4	2.2	16.0	8.5
Fipronil	0.06	11.8	4.0	5.6	2.2	7.2	17.5	6.8	1.6	16.2	6.5
Imidacloprid	0.05	21.3	4.2	5.7	1.0	5.6	8.0	6.2	2.7	18.3	7.9
Lambda-cyhalothrin	0.04	17.9	5.4	4.9	2.0	5.8	9.0	3.0	1.3	18.2	4.6
Oxamyl	0.28	19.7	6.1	4.3	1.6	7.4	16.3	5.6	4.4	11.3	6.7
Carbofuran	0.28	20.7	2.0	5.1	1.0	4.4	16.0	6.0	2.5	17.0	7.8
Dimethoate	0.28	17.4	4.5	5.4	0.3	5.3	13.9	5.7	3.7	14.2	6.5
Nontreated	--	50.8	40.4	43.0	48.7	16.8	26.7	11.8	23.4	47.1	57.3
LSD (0.05)	--	9.0	7.4	2.3	4.0	4.0	8.0	4.7	4.0	8.6	5.2

[a]Data represent an average across locations (St. Joseph and Winnsboro, LA) for 1999.

[b]Abbreviations: IPOLA, pitted morningglory; SEBEX, hemp sesbania; SIDSP, prickly sida; ABUTH, velvetleaf; IPOHE, mix of entireleaf and ivyleaf morningglory.

[c]Pyrithiobac co-applied with all insecticides at 0.07 kg ai/ha.

reported (Allen and Snipes 1995: Minton et al. 2000). Jordan et al. (1993a) also reported no effect on cotton growth from pyrithiobac co-applied with the insecticides acephate, carbaryl, or dimethoate. However, data from the thrips control experiments indicate that pyrithiobac may antagonize certain insecticides. Oxamyl and dimethoate applied alone in two of three experiments resulted in a greater reduction in thrips larvae than when co-applied with pyrithiobac. The 2 DAT rating in the adjuvant study suggests that some adjuvants may have toxicity to thrips. However, by 5 DAT thrips larvae in the cotton treated with adjuvant alone was similar to the nontreated and less than acephate alone. Although adjuvants evaluated may affect thrips control with insecticides, they appear to have little toxicity to thrips when applied alone. Thrips larvae are a better measure of efficacy due to mobility of adults. The efficacy of pyrithiobac against specific weed species was not affected by the addition of selected insecticides. These data suggest that co-applications of pyrithiobac and insecticides can be safe for postemergence over-the-top applications to 2 to 3 node cotton and effective in controlling early season weed pests. However, potential reductions in thrips control with the co-applications need further investigation.

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CHAPTER 3

PYRITHIOBAC PHYTOTOXICITY TO COTTON PREDISPOSED TO THRIPS INJURY

Introduction

Pyrithiobac (trade name Staple 85WP [1]) was one of the first postemergence (POST) over-the-top broadleaf herbicides labeled in cotton with acceptable crop safety. Although, other herbicides have been labeled for POST over-the-top application, they were primarily limited to salvage treatments that often delayed cotton maturity and reduced yields (Frans et al. 1971;Guthrie and York 1989; Snipes and Byrd 1994). Jordan et al. 1993b reported no effect on seed cotton yield, micronaire, fiber length, fiber length uniformity, or fiber strength in cotton treated with up to four times the labeled use rate of pyrithiobac (0.28 kg ai/ha). Likewise, applications of up to 0.2 kg ai/ha POST resulted in no reductions in cotton plant population, height, yield, or fiber quality (Keeling et al. 1993). Although no yield reductions have been reported from POST applications of pyrithiobac, Keeling et al. (1993) reported reduced yield and micronaire from 0.1 and 0.2 kg/ha pyrithiobac preplant incorporated (PPI) and 0.2 kg/ha pyrithiobac preemergence (PRE).

Researchers have reported injury in the form of plant chlorosis and stunting (Crawford et al. 1989; Sims et al. 1991; Vargas et al. 1998; Vidrine et al. 1990). This injury was transient and was not evident two to three weeks after application. Many abiotic and biotic factors may influence cotton sensitivity to pyrithiobac. After pyrithiobac was labeled and large scale applications were made, significant injury was observed. Corkern et al. 1999 reported greater phytotoxicity with pyrithiobac when

[1] Staple product label. E. I. du Pont de Nemours and Co. Wilmington, DE 19898.

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applied to cotton in saturated soil conditions. Another possible explanation was that injury to cotton seedlings by thrips (*Frankliniella* spp.) may play a role in pyrithiobac phytotoxicity (Baldwin 1996). Thrips injure plants by scraping holes in the plant tissue and consuming the cell exudates. Leaves twist, become distorted, and tear as a result of abnormal growth (Telford and Hopkins 1957). Leaves typically exhibit a silvery spotting on the underside as a result of feeding. This often leads to reductions in main stem height, leaf area, and delays in maturity, and reduced yields (Ballard 1951; Carter et al. 1989; Dunnam and Clark 1937; Hawkins et al. 1966; Leser 1989; Watts 1937). Less than 2% of pyrithiobac is translocated out of the treated leaf where metabolism occurs (Corkern et al. 1998), therefore, if the leaf is damaged by thrips reduced metabolism may occur predisposing the cotton to injury. Reduced tolerance of some cotton varieties has been attributed to reduced metabolism (Corkern et al. 1998). Stress imposed on plants due to thrips feeding may affect the ability of the plant to metabolize pyrithiobac, therefore, leading to injury. The pyrithiobac label states that under certain conditions such as cool temperatures, wet soil, and thrips injury that cotton tolerance may be decreased. A second possible explanation was improper bandwidth adjustment over the cotton row leading to an application rate of pyrithiobac higher than the labeled rate (Personal communication, Eric Castner E.I. DuPont). For instance, if the band width was to be 50 cm and the height was improperly adjusted and the band was only 10 cm the rate would be increased by a magnitude of five. The objectives of these studies were to determine if thrips injury influenced cotton tolerance to pyrithiobac and to quantify cotton injury with respect to pyrithiobac rate.

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Materials and Methods

Thrips injury study. Experiments were conducted at the Northeast Research Station near St. Joseph, LA, and the Macon Ridge Location of the Northeast Research Station near Winnsboro, LA, in 1997, 1998, and 1999. Tests at St. Joseph were conducted on a Commerce silt loam (fine-silty, mixed, nonacid, thermic, Aeric Fluvaquent) with 0.93% organic matter and pH of 7.1 and at Winnsboro on a Gigger silt loam (fine-silty, mixed, thermic, Typic Fragiudualfs) with 0.92% organic matter and pH of 5.8. Stoneville 474 (Stoneville Pedigree Seed Co., Memphis, TN 38115) cotton at a rate of 12 to 15 seed per meter was planted May 8, May 29, and May 13 in 1997, 1998, and 1999, respectively, at St. Joseph and May 7, May 6, and May 13 in 1997, 1998, and 1999, respectively, at Winnsboro. Experiments were furrow irrigated as needed beginning at first bloom at Winnsboro in 1997 and 1999.

The experimental areas were conventionally tilled and treated with trifluralin [2,6-dinitro-*N,N*-dipropyl-4-(trifluromethyl)benzamine; Treflan 0.84 kg ai/ha] PPI in 1997 and pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzamine; Prowl 1.12 kg ai/ha] PRE in 1998 and 1999 at St. Joseph and fluometuron {*N,N*-dimethyl-*N*=[3-(trifluromethyl)phenyl]urea; Meturon 0.84 kg ai/ha} PRE each year at Winnsboro. Preplant incorporated applications were made prior to bed formation and PRE applications were made at planting. Metalaxyl {(*R*)-2-[(2,6-dimethylphenyl)-methoxyacetylamino]-propionic acid methyl ester; Ridomil Gold} fungicide was applied in-furrow at planting in all experiments.

Experiments were arranged as a split-plot design with four replications. The main plot treatments were aldicarb {[2-methyl-2-(meththio)propionaldehyde *O*-(methylcarbamoyl)oxime; Temik, 0.56 kg/ha} applied in the seed furrow at planting or

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no aldicarb. Sub-plot treatments were pyrithiobac at 0.035, 0.07, 0.14, 0.28, 0.56, and 1.22 kg ai/ha, which correspond to 0.5, 1, 2, 4, 8, and 16 times the labeled rate. A nontreated control was included for each main plot factor. A nonionic surfactant, AG-98[2] at 0.25% v/v, was included in each treatment. Plot size consisted of 4 rows by 12 m at St. Joseph and 4 rows by 14 m, 3 rows by 14 m, and 2 rows by 17 m in 1997, 1998, and 1999, respectively, at Winnsboro. Cotton was thinned to 6 to 9 plants/m prior to application of pyrithiobac. Treatments were applied when cotton reached 2 to 3 nodes. Treatments were applied to two center rows of each plot with a tractor mounted compressed air sprayer at St. Joseph and a CO_2 pressurized backpack sprayer at Winnsboro each calibrated to deliver 140 L/ha.

Thrips were monitored prior to pyrithiobac applications by randomly collecting 20 plants from both the aldicarb treated and nontreated plots, placing them in 0.94 L glass jars, and removing the thrips by using whole plant washing techniques as described by Burris et al. (1990). At 7, 14, and 28 days after treatment (DAT), cotton plants were removed from a 0.5 m section of row and used to determine leaf area and total main stem nodes. Leaf area was determined using a LI-COR 3000[3] leaf area meter and is presented on a per plant basis. Leaf area was measured only at 28 DAT in 1997. Main stem height was determined by randomly measuring 10 plants from each plot at the same rating intervals mentioned above. Main stem node number at square initiation was determined from plants collected for leaf area 28 DAT. Only data from the 14 and 28 DAT ratings will be discussed. Nodes above white flower (NAWF) were determined weekly after flower initiation until plants averaged no more than 5 nodes. Seed cotton yield was determined by mechanically harvesting the center two rows of each plot with a spindle

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[2] AG-98 is a blend of alkylaryl polyxethylene glycols and alchol. Rohm and Haas Co., Philadelphia, PA 19106-2399.
[3] LICOR, Inc. Lincoln, NE 68504

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type cotton picker. Leaf area main stem height and seed cotton yield will be discussed as a percent reduction from the nontreated.

Terminal removal study. An additional study was conducted in 1997, 1998, and 1999 at the Macon Ridge Location of the Northeast Research Station near Winnsboro, LA, to further investigate the influence of thrips on cotton tolerance to pyrithiobac. Stoneville 474 cotton was planted May 27 and May 7 in 1997, 1998, respectively, and Delta and Pine 20B (Delta and Pine Land Co., Scott, MS 38772) cotton was planted May 13 in 1999. Fluometuron at 0.84 kg ai/ha was applied PRE and metalaxyl was applied in the seed furrow at planting. The experimental design was a randomized complete block with a factorial arrangement of treatments and 3 or 4 replications. Factor one was insecticide treatments and included aldicarb (Temik 15G; 0.56 kg ai/ha) applied in the seed furrow at planting; no insecticide applied at planting; imidacloprid {1-[(6-cloro-3-pryimidinyl)methyl]-*N*-nitro-2-imidazolidinimine; Admire; 0.22 kg ai/ha} applied in the seed furrow at planting; or aldicarb applied in the seed furrow at planting with cotton terminals removed. Factor two was pyrithiobac (0.07 kg ai/ha) applied 2, 4, or 8 node cotton.

Terminals were removed to simulate thrips injury prior to the 2 node application by hand removing only the terminal bud portion of the plant. This treatment was included to simulate destruction of the terminal bud by thrips feeding and was sufficient to cause most plants to loose apical dominance. Pyrithiobac treatments were applied using a compressed air sprayer calibrated to deliver 140 L/ha. A nonionic surfactant, AG-98 at 0.25% v/v, was included in all treatments. Plot size consisted of 2 rows by 9 m (1-m spacing) in 1997, 2 rows by 14 m (1-m spacing) in 1998, and 2 rows by 17 m (1-m spacing) in 1999.

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Thrips numbers were monitored by collecting 20 plants from each insecticide treatment and processing as described in the previous study. Cotton leaf area, main stem height, and total main stem nodes were determined 2, 4, and 8 weeks after each application. Only two week data will be discussed due to lack of significant differences at 4 and 8 weeks. Number of main stem nodes at square initiation was determined at the time leaf area was measured four weeks after treatment. Nodes above white flower were determined weekly after the first week of flowering until plants averaged no more than 5 nodes. Seed cotton yield was determined by harvesting the center two rows of each plot with a spindle type cotton picker.

Results and Discussion

Thrips injury study. A pyrithiobac by aldicarb interaction was not observed indicating that the presence of thrips did not affect cotton tolerance to pyrithiobac when applied postemergence. However, significant differences were observed among pyrithiobac rates. Therefore, data were averaged across aldicarb treatments. The labeled rate of pyrithiobac (0.07 kg/ha) was equivalent to the nontreated for all measurements, therefore all comparisons will be made with the labeled rate of pyrithiobac. A location by pyrithiobac interaction (P=0.0312) was observed for cotton leaf area 14 DAT. At St. Joseph, cotton leaf area was reduced by 0.56 (36%) and 1.22 kg/ha (33%), which was greater than for the labeled rate (Table 3.1). At Winnsboro, 0.28, 0.56, and 1.22 kg/ha pyrithiobac reduced cotton leaf area compared with the labeled rate. It would be expected that any early season injury due to herbicide would delay growth and reduce leaf area. A year by location by pyrithiobac interaction (P=0.0307) was observed 28 DAT. All treatments with the exception of pyrithiobac at 0.56 kg/ha were equivalent to

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Table 3.1. Cotton leaf area reduction from the nontreated 14 and 28 days after application of pyrithiobac at St. Joseph and Winnsboro, LA.[a]

	14 DAT[b]		28 DAT				
			St. Joseph		Winnsboro		
Pyrthiobac rate	St. Joseph	Winnsboro	1997	1999	1997	1998	1999
kg ai/ha	%						
0.04	6 a[c]	15 a	4 a	7 a	3 a	8 a	13 a
0.07	13 a	11 a	2 a	5 a	5 a	10 ab	11 a
0.14	20 ab	23 ab	3 a	2 a	6 a	11 ab	13 a
0.28	21 ab	37 b	6 a	10 a	8 a	15 abc	23 a
0.56	36 b	39 b	32 b	4 a	5 a	28 bc	30 a
1.22	33 b	58 c	19 ab	13 a	16 a	31 c	57 b

[a] Data presented as a percent reduction from the nontreated control. DAT = days after treatment.

[b] Data represent an average across years.

[c] Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer means separation procedure.

the labeled rate at St. Joseph in 1997 (Table 3.1). No differences were observed among treatments at St. Joseph in 1999 or at Winnsboro in 1997 at 28 DAT. Pyrithiobac at 1.22 kg/ha reduced cotton leaf area 31 and 57% in 1998 and 1999, respectively, compared with the labeled rate (10 and 11%, respectively) 28 DAT at Winnsboro. (Table 3.1).

The year by location by pyrithiobac interaction was also significant for cotton main stem height 14 DAT (P=0.0287). At St. Joseph, pyrithiobac at 1.22 kg/ha reduced cotton height (21%) compared with the labeled rate (10%) in 1998, and no differences among pyrithiobac rates were observed in 1997 or 1999 (Table 3.2). At Winnsboro, cotton main stem height 14 DAT was reduced by pyrithiobac at 1.22 kg/ha in 1998 and 0.56 and 1.22 kg/ha in 1999 compared with the labeled rate. The year by pyrithiobac interaction was significant (P=0.0017) for cotton height 28 DAT. Height was not reduced more than 8% by any pyrithiobac rate in 1997 or 10% in 1998 at either location. Compared with the labeled rate of pyrithiobac, 0.28, 0.56 and 1.22 kg/ha reduced cotton height in 1999 at 28 DAT.

Total main stem nodes were not affected by pyrithiobac applications at any rating date. Main stem node number at square initiation averaged across experiments was equivalent at St. Joseph for all pyrithiobac rates. In contrast, at Winnsboro main stem node number was increased by an average of 1.2 nodes in cotton treated with 1.22 kg/ha pyrithiobac compared with the labeled rate (Table 3.3). A significant location by pyrithiobac (P = 0.0205) interaction was observed for NAWF during the first week of flowering. No differences were noted among pyrithiobac rates at St. Joseph. At Winnsboro, for NAWF 1.22 kg/ha pyrithiobac was greater than the nontreated control, but, was not different from the labeled rate. The year by location by pyrithiobac

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Table 3.2. Cotton main stem height reduction following application of pyrithiobac at St. Joseph and Winnsboro, LA.[a]

	14 DAT						28 DAT[b]		
	St. Joseph			Winnsboro					
Pyrithiobac rate	1997	1998	1999	1997	1998	1999	1997	1998	1999
kg ai/ha	%								
0.04	2 a[c]	7 a	3 a	5 a	10 a	2 a	5 a	3 a	2 a
0.07	3 a	10 a	2 a	6 a	9 a	4 a	5 a	3 a	3 a
0.14	3 a	5 a	5 a	4 a	10 a	4 a	7 a	6 a	5 a
0.28	7 a	11 ab	5 a	0 a	11 a	5 a	5 a	6 a	12 b
0.56	4 a	17 ab	5 a	8 a	15 ab	17 b	7 a	6 a	27 c
1.22	3 a	21 b	11 a	5 a	23 b	28 b	8 a	10 a	38 d

[a] Data presented as a percent reduction from the nontreated control. DAT = days after treatment.
[b] Data represent an average across locations.
[c] Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer means separation procedure.

Table 3.3. Effect of pyrithiobac rate on total number of main stem nodes of cotton at square initiation at St. Joseph and Winnsboro, LA[a].

Pyrithiobac rate	St. Joseph	Winnsboro
kg ai/ha		
	no.	
0.04	6.9 a[b]	7.1 a
0.07	6.8 a	6.8 a
0.14	7.0 a	7.1 a
0.28	7.0 a	6.9 a
0.56	6.8 a	7.3 ab
1.22	7.0 a	8.0 b
Nontreated	6.9 a	6.9 a

[a] Data represent an average across years.
[b] Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer means separation procedure.

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(P = 0.0256) interaction was significant during the second week of flowering. No differences were noted among pyrithiobac rates at St. Joseph in any year or at Winnsboro in 1997 or 1998 (Table 3.4). In 1999 at Winnsboro, pyrithiobac at 1.22 kg/ha increased NAWF during the second week of flowering compared with the labeled rate. No differences were observed among pyrithiobac rates when NAWF counts were made thereafter (data not shown).

A year by pyrithiobac (P = 0.0108) interaction was observed for seed cotton yield. Yield was 2140 to 2267 in 1997, 765 to 967 in 1998, and 2768 to 3108 kg/ha. No differences were observed among pyrithiobac rates averaged across locations in 1997 or 1999 (Table 3.5). However, in 1998, 1.22 kg/ha pyrithiobac reduced seed cotton yield compared with the labeled rate (19 vs. 8%).

Terminal removal study. Analysis of variance revealed no differences 14 DAT among the four insecticide treatments or any interactions of insecticide treatment and pyrithiobac timings. These data suggest that neither thrips injury (due to no insecticide treatment) nor removal of the terminal enhanced cotton sensitivity to pyrithiobac. Although terminal removal did cause most plants to produce multiple main stems, this did not result in any delays in cotton maturity or seedcotton yield. Other researchers have also reported that mechanical terminal removal did not delay cotton maturity (Ihrig et al. 1996; Mann et al. 1995). However, labeled rate of pyrithiobac 14 DAT regardless of timing reduced cotton leaf area 7 to 13% compared with the nontreated control (Table 3.6). Main stem height was reduced only by applications to 2 and 4 node cotton (5.5 and 6.0%). No differences were observed for main stem node number at square initiation, NAWF, or seed cotton yield (data not shown).

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Table 3.4. The effect of pyrithiobac on number of cotton nodes above white flower during the second (NAWF 1) and third week of flowering (NAWF 2) at St. Joseph and Winnsboro, LA.

	NAWF 1[a]		NAWF 2					
			St. Joseph			Winnsboro		
Pyrthiobac rate	St. Joseph	Winnsboro	1997	1998	1999	1997	1998	1999
kg ai/ha	no.							
0.04	7.4 a	6.0 a	6.3 a	6.4 a	5.6 a	4.8 a	3.9 a	4.1 a
0.07	7.5 a	6.2 ab	6.1 a	6.5 a	5.6 a	4.8 a	3.7 a	4.1 a
0.14	7.6 a	6.2 ab	6.2 a	6.2 a	5.1 a	5.1 a	4.0 a	4.5 a
0.28	7.2 a	6.3 ab	6.5 a	6.4 a	5.0 a	4.6 a	4.2 a	4.6 a
0.56	7.5 a	6.4 ab	6.5 a	6.2 a	5.1 a	4.7 a	4.0 a	5.1 a
1.22	7.5 a	6.7 b	6.5 a	6.8 a	5.2 a	4.4 a	4.4 a	5.4 b
Nontreated	7.4 a	6.0 a	6.7 a	7.1 a	5.0 a	5.1 a	3.8 a	3.8 a

[a] Data averaged across years.

[b] Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer means separation procedure.

Table 3.5. **Seed cotton yield reduction following application of pyrithiobac at St. Joseph and Winnsboro, LA[a].**

Pyrithiobac rate	Seed cotton yield[b]		
	1997	1998	1999
(kg/ha)		%	
0.035	4 a	7 a	2 a
0.07	4 a	8 a	4 ab
0.14	3 a	6 a	3 ab
0.28	2 a	7 a	6 ab
0.56	3 a	9 a	5 ab
1.22	5 a	19 b	12 b

[a] Data presented as a percent reduction from the nontreated control.
[b] Data represent an average across locations.
[c] Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer means separation procedure.
[d]Nontreated cotton yielded 2140, 914, and 2973 kg/ha in 1997, 1998, and 1999, respectively.

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Table 3.6. Cotton leaf area and main stem height 14 days after pyrithiobac application to 2, 4, and 8 node cotton at St. Joseph and Winnsboro, LA[a].

Timing	Leaf Area[b]	Height[b]
	—%—	
2 node	13 c[c]	5.5 b
4 node	12 bc	6.0 b
8 node	7 b	2.5 a
Nontreated	0 a	0 a

[a]Data represent an average across years, locations, and aldicarb and imidacloprid treatments. Pyrithiobac rate was 0.07 kg ai/ha.
[b]Data represents leaf area per plant. Leaf area and height data presented as a percent reduction from the nontreated control.
[c]Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer means separation procedure.

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These data suggest that thrips injury does not change cotton sensitivity to pyrithiobac. Of significance is that injury from pyrithiobac can mimic thrips injury. These data do suggest that there is potential for cotton injury with high rates of pyrithiobac. Situations in which band width is improperly adjusted, significant injury can occur and may result in delays and reduced yields. However, differential injury among years and locations suggest that environmental conditions can have a profound effect on cotton sensitivity to pyrithiobac. Injury from pyrithiobac may delay cotton fruiting and maturity. Although significant reductions in leaf area and main stem height occurred at lower rates, only in one year at the highest rate (1.22 kg/ha) was yield reduced compared with the labeled rate. However, delays in maturity and harvest may present problems even if yields are not reduced. Delays in maturity may result in the need for additional insecticide applications or may extend the growing season and harvest into adverse seasonal weather conditions. Results agree with other researchers that pyrithiobac up to four times the labeled rate does not reduce cotton yields (Jordan et al. 1993b; Keeling et al. 1993). However, these researchers did address the potential influence that thrips injury or terminal removal to simulate thrips injury had on cotton tolerance to pyrithiobac. Pyrithiobac can be a safe and effective component in a cotton weed control program.

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CHAPTER 4

THE EFFECT OF COOL STRESS AND TERMINAL REMOVAL ON COTTON TOLERANCE TO PYRITHIOBAC AND INSECTICIDE CO-APPLICATIONS

Introduction

Pryithiobac[1] {2-chloro-6-[(4,6-dimethoxy-2-prymidinyl)thio]benzoic acid; trade name Staple 85WP} (Anonymous 1998) was introduced as the first broadleaf weed herbicide that could be applied to the foliage of cotton with acceptable crop safety (Jordan et al. 1993b; Keeling et al. 1993). Pyrithiobac represents a new class of herbicides (benzoates), which inhibits acetolactate synthase (E.C.4.1.3.18), the same as that of the sulfonylureas (Anonymous 1998). Pyrithiobac can be applied postemergence when cotton reaches one node. These applications may occur when conditions are unfavorable to cotton growth and plants are damaged by insects. These conditions may affect the sensitivity of cotton to pyrithiobac.

Cotton planting typically begins in the month of April in the Mid-south. Environmental conditions at this time of year may reduce the growth and development of the crop. Weeds and insect pests may also infest cotton fields at the same time causing significant yield reductions when not controlled. Thrips, (Thysanoptera: Thripidae), invade and feed on cotton from the cotyledon to early stages of growth. Thrips injure plants by scraping holes in the plant tissue and consuming the cell exudates as they leak out. Leaves twist, become distorted, and tear as a result of abnormal growth (Telford and Hopkins 1957). Leaves typically exhibit a silvery spotting on the underside as a result of feeding. Thrips feeding often results in reduced leaf area and plant main stem height,

[1] Staple product label. E. I. du Pont de Nemours and Co. Wilmington, DE 19898.

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delayed fruiting, and reduced yields (Ballard 1951; Carter et al. 1989; Hawkins et al. 1966; Leser 1986; Roberts and Rechel 1996; Wilson 1986).

Not only biotic factors affect growth, but abiotic factors such as cool temperature stress may reduce cotton growth and development. The pyrithiobac label identifies several factors, including cool temperatures (less than 15 C), which may reduce cotton tolerance. Cool temperatures have been reported to reduce the growth of cotton. Reddy et al.(1991) reported that cotton growth was greatly reduced under 20/10 C and 25/15 C day/night temperature compared with 30/20 C day/night temperature. Cotton exposed to 26/17 C day/night temperature produced less leaf area and dry weight, and main stem height was reduced compared with plants grown in 32/23 C day/night temperatures (Flint et al. 1983).

Enhanced crop sensitivity due to cool temperature stress has been reported with other ALS inhibiting herbicides (Beyer et al. 1988). Cotton sensitivity to MSMA was increased when cotton was under cool stress conditions (Keeley and Thullen 1971). Cotton injury with pyrithiobac and the combination of pyrithiobac plus malathion [*S*-1,2-di(ethoxycarbonyl)ethyl *O,O*-dimethyl phosphorodithioate] was greater under cool stress (21/13 C day/night) conditions compared with a warm (30/21 C day/night) environment (Allen and Snipes 1995). In contrast, Murray and Schroeder (1999) reported that pima cotton sensitivity to pyrithiobac was not influenced by cool (20/12 C day/night) temperatures. Although others have reported that temperature did not increase pyrithiobac injury to cotton, they did not investigate the influence of terminal damage or insecticides (Harrison et al. 1996; Jennings et al. 1999). The objective of this study was

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to determine the effect of cool temperature stress and terminal bud removal on cotton sensitivity to pyrithiobac and pyrithiobac plus insecticide combinations.

Materials and Methods

Experiments were conducted in 1999 and 2000 in a greenhouse and growth chamber at Baton Rouge LA, on the Louisiana State University campus to determine the effect of cold temperature stress and terminal damage on cotton tolerance to pyrithiobac and pyrithiobac and insecticide combinations. Stoneville 474 (Stoneville Pedigree Seed Co., Memphis, TN 38115) cotton was planted in 21.6 by 17 cm plastic pots containing a 3:1 mixture of Commerce silt loam soil (fine-silty, mixed nonacid, thermic Aeric Fluvaquents) and Jiffy Mix Plus[3] on February 6 and 18 in 1999 and on January 5 and February 9 in 2000. Due to growth chamber restrictions only two replications could be planted at one time. The experimental design was a split plot with treatments arranged as a two factor factorial within each split. Main plots were temperature regimes established using the greenhouse and growth chamber. The greenhouse was maintained at 35/18 C day/night and growth chamber was maintained at 22/10 C day/night with a 12 hour day length in each. These temperatures were chosen after personal communication with Dr. Merritt Holman. Factor one was cotton terminal bud removal to simulate thrips feeding damage or no terminal damage. Terminal bud damage was accomplished by carefully removing by hand only the terminal bud portion of the plants just prior to treatment application. Factor two was herbicide and insecticide combinations. The insecticides included acephate (*O,S*-dimethylacetylphoramidothioate; Orthene 90SP[3] , 0.37 kg ai/ha),

[2] Potting mixture, Jiffy Mix Plus, Jiffy Products of America, Inc., Batavia, IL 60510.
[3] Orthene product label. Valent USA Co. Walnut Creek, CA 94596-8025.

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malathion (*O,O*-dimethyl *S*-(dicarbethoxyethyl)phosphorodithionate; Malathion 5E[4], 1.4 kg ai/ha), and dimethoate {*O,O*-dimethyl *S*-[*N*-methylcarbamoyl)methyl] (phosphororithioate); Dimate 4EC[5] , 0.28 kg ai/ha}. Pyrithiobac was applied alone and co-applied with each insecticide at 0.07 kg ai/ha. A nonionic surfactant, AG-98[6], was added at 0.25% (v/v).

Cotton was grown in the greenhouse until the two true leaf stage of growth. The plants to receive the cool temperature stress were moved into the growth chamber and allowed to equilibrate to this environment for 48 hours. After 48 hours, the cotton plants were removed from the growth chamber and herbicide/insecticide treatments were applied using an air assisted track spray chamber calibrated to deliver 140 L/ha. Treatments were applied to cotton that remained in the greenhouse one day prior to treating plants in the growth chamber. After treatment, plants from the growth chamber were placed back in the growth chamber for an additional 48 hours and then moved into the greenhouse.

Data collected included visual injury ratings and cotton main stem height 7, 14, and 28 days after treatment (DAT). Visual injury was based on a scale of 0 (no injury) to 100% (plant death). At 14 DAT, one plant from each pot was harvested at soil level and used to determine leaf area, total main stem nodes, and dry weight. Leaf area was measured using a LI-Cor LI-3000[7]. The remaining plants were monitored and time period to square initiation was recorded for each remaining plant. At that time the remaining plants were harvested and leaf area, total main stem nodes, and dry weights were determined. Cotton main stem height and leaf area is presented as a percent

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[4]Malathion product label. Micro Flo Co. Lakeland, FL 33807.
[5] Dimate product label. Terra Industries Inc., Sioux City IA, 51102-6000.

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reduction from the nontreated control. Data were subjected to analysis of variance and means were separated using Tukey-Kramer at a 0.05 level of probability.

Results and Discussion

Experiment by treatment interactions were not observed, therefore, data were averaged across experiments. The temperature regime by treatment interaction was significant for cotton injury 7 ($P = 0.0049$) and 14 ($P = 0.0131$) DAT. Cotton injury 7 DAT under the normal temperature regime ranged from 27 to 30% and was not different among pyrithiobac and pyrithiobac plus insecticide combinations (Table 4.1). In the cool temperature environment, pyrithiobac plus acephate resulted in 16% injury which was less than all other treatments. Averaged across pyrithiobac and insecticide treatments, there were no differences between temperatures and cool temperature stress treatments. Although leaf chlorosis was not increased, significant leaf necrosis was observed from applications of pyrithiobac plus malathion or dimethoate 7 DAT and appeared to be caused by the added effect of the AG-98 and the oil emulsifiers in these insecticides. Minton and Senseman (2000) reported similar injury with pyrithiobac plus malathion and CGA-362622 plus malathion or dimethoate. Cotton injury at 14 DAT was no greater than 11% (Table 4.1). Cotton injury at 7 and 14 DAT was transient and was not observed at 28 DAT.

The main effect of treatment was significant for cotton main stem height and leaf area 14 and 28 DAT (Table 4.2). Although differences were noted among treatments for cotton main stem height 14 and 28 DAT, the reductions were no greater than five percent

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[6] AG-98 is a blend of alkylaryl polyxethylene glycols and alchol. Rohm and Haas Co., Philadelphia, PA 19106-2399.
[7] LICOR, Inc. Lincoln, NE 68504

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Table 4.1. The effect of cool and warm ambient temperature regime on cotton injury 7 and 14 days after application from pyrithiobac and pyrithiobac plus insecticides across two experiments[a].

Treatment		Cotton injury			
		7 DAT		14 DAT	
		Cold[b]	Warm[b]	Cold	Warm
	kg ai/ha	%			
Pyrithiobac	0.07	38 b[c]	30	9	6
Pyrithiobac + acephate	0.07 + 0.37	16 a	30	4	7
Pyrithiobac + malathion	0.07 + 1.4	34 b	30	11	5
Pyrithiobac + dimethoate	0.07 + 0.28	33 b	27	6	5

[a]Data represent an average across cotton where terminals were removed or not removed bud removal.
[b]Represents cool (22/10 C day/night) stress environment and warm (35/18 C day/night) environment.
[c]Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer.

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Table 4.2. **Percent recution in cotton main stem height and leaf area 14 and 28 days after application of pyrithiobac and pyrithiobac plus insecticide combinations averaged across two experiments.**[a]

Treatment		Height		Leaf area	
		14 DAT	28 DAT	14 DAT	28 DAT
	kg ai/ha	%			
Pyrithiobac	0.07	5 b[b]	4 a	11 b	8 b
Pyrithiobac + acephate	0.07 + 0.37	5 b	3 ab	7 ab	7 b
Pyrithiobac + malathion	0.07 + 1.4	3 a	2 ab	11 b	4 ab
Pyrithiobac + dimethoate	0.07 + 0.28	4 b	3 ab	14 b	7 b

[a]Data represent and average across temperature and terminal removal.
[b]Means in a column followed by the same letter are not different at a 0.05 level of probability according to Tukey-Kramer.

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(Table 4.2). Compared with the nontreated control 14 DAT, cotton leaf area was reduced (11%) with pyrithiobac alone and with pyrithiobac plus malathion (11%) or dimethoate (14%), but not with pyrithiobac plus acephate (7%) (Table 4.2). There were no differences among the pyrithiobac plus insecticide combinations. At 28 DAT, no differences were noted among pyrithiobac plus insecticide combinations, however, all treatments with the exception of pyrithiobac plus malathion reduced leaf area 7 to 8 % compared with the nontreated control.

Total main stem nodes were not affected by pyrithiobac or pyrithiobac plus insecticide treatments at either rating date (data not shown). However, the main effects of temperature regime ($P = 0.0001$) and terminal removal ($P = 0.0001$) were significant for total main stem nodes 14 DAT. Total main stem nodes 14 DAT were reduced by approximately one node by cool temperature stress (5.1 vs. 4.2) or terminal bud removal (5.2 vs. 4.2). Although terminal removal reduced total main stem nodes 28 DAT, the difference was only 0.3 nodes indicating that plants were recovering. The main effect of terminal removal was significant ($P = 0.0001$) for total main stem nodes at square initiation. Total number of nodes at square initiation was increased by one (7.5 vs. 6.5) as a result of terminal removal. The main effect of temperature ($P = 0.0001$) and terminal removal ($P = 0.0001$) were significant for days to square initiation. Cool temperature stress or terminal bud removal increased days to square initiation by one day (37 vs. 38).

These data are consistent with others and suggest that cool temperature stress did not affect cotton sensitivity to pyrthiobac or pyrithiobac plus insecticide co-applications (Allen and Snipes 1995; Jennings et al. 1999). Cotton fruiting can be delayed due to cool temperature stress and removal of the terminal bud portion of the plant. This supports

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field observations that thrips damage resulting in death of the terminal bud can delay cotton maturity. This study also suggests that pyrithiobac applications during times of cool temperature stresses should not further enhance injury that would normally be expected. Other factors such as drought conditions or high temperatures may increase pyrithiobac phytotoxicity to cotton. These factors may need to be investigated to determine which influence cotton tolerance to pyrithiobac. However, it is possible that a combination of two or more of these factors may have a greater influence than any one alone. Also, as was suggested by Corkern et al. 1999, variety tolerances may vary.

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CHAPTER 5

SUMMARY

Field studies were conducted at the Northeast Research Station near St. Joseph, LA, and the Macon Ridge location of the Northeast Research Station near Winnsboro, LA, to investigate possible interactions of pyrithiobac and insecticide combinations in cotton. In addition, field studies were conducted to determine the role of thrips on cotton sensitivity to pyrithiobac. Controlled environment experiments evaluated the effect of environmental conditions and terminal removal on cotton response to pyrithiobac plus insecticides.

Cotton leaf area and total main stem height were not affected by any pyrithiobac plus insecticide combinations compared with the nontreated. Averaged across years, locations, and treatments, total main stem nodes at square initiation was 6.5. Days to square initiation and first flower were 36 and 60, respectively, averaged across years, locations, and treatments. Cotton in these experiments was growing normally and differences were a result of variations in irrigation, rainfall, and heat unit accumulations. Seed cotton yield was not negatively affected by any pyrithiobac plus insecticide combination. In most cases the combination of pyrithiobac plus insecticide did not influence thrips control. However, acephate alone in one experiment and Oxamyl alone in two experiments reduced thrips larvae more than when in combination with pyrithiobac. Weed control was 92 to 99% for pitted morningglory, hemp sesbania, and entireleaf/ivyleaf morningglory, and 69 to 75% for prickly sida, and 81 to 93% for velvetleaf, and was consistent with previous data from other research.

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Presence of thrips did not increase the sensitivity of cotton to pyrithiobac. However, differences in cotton response among pyrithiobac rates were observed. Cotton leaf area or height was not reduced by pyrithiobac applied up to four times the labeled rate compared with nontreated cotton. Leaf area reductions, ranging from 36 to 58%, were noted with eight and sixteen times the labeled rate. Cotton sensitivity to pyrithiobac appeared to be related to environment as evidenced by the variation in growth reductions among years and locations. Significant reductions in cotton height were observed, however, varied among years and locations. At Winnsboro, pyrithiobac at 1.22 kg ai/ha increased total main stem nodes at square initiation by 1.2 nodes. Although significant reductions were observed in leaf area and main stem height, cotton yield was reduced only (19%) in 1998 by pyrithiobac at 1.22 kg/ha. In an additional study, which included different timings of pyrithiobac and mechanical terminal injury, the presence of thrips or mechanical injury did not influence cotton sensitivity to pyrithiobac.

In the controlled environment studies, temperature or terminal removal did not influence cotton sensitivity to pyrithiobac. Cool temperature stress and terminal removal decreased total main stem nodes and increased total main stem nodes at square initiation by approximately one node. Although injury was noted with insecticide treatments, it appeared that the injury was caused by the surfactant in combination with the oil emulsifiers in the liquid formulated insecticides . Injury was transient and was less than 5% 28 DAT.

Due to economics, producers are at present applying pyrithiobac in combination with insecticides for control of early season weed and insect pests. Data from these

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studies suggest that pyrithiobac plus insecticides do not result in any adverse effects to the cotton crop nor do the combinations result in reduced control of the target pests.

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VITA

Richard W. Costello was born February 24, 1968, in Greenville, Mississippi. Richard grew up on a farm near the town of Oak Grove, Louisiana. He graduated from Oak Grove High School in 1986. He attended Louisiana Tech University and received a bachelor of science degree in agricultural business in 1992. Richard then attended the University of Arkansas, Fayetteville, Arkansas where he received his master of science degree in weed science. Currently, he is a doctorial candidate in the Department of Plant Pathology and Crop Physiology at Louisiana State University.

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Richard W. Costello

Major Field: Plant Health

Title of Dissertation: Influence of Pyrithiobac and Insecticide Combinations on Cotton Growth and Early Season Pest Control

Approved:

James L. Griffin
Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Brad C. Venuto

Date of Examination:

July 31, 2000

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